Journal of Theoretical and Applied Information Technology
30th April 2013. Vol. 50 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

# A SKEW ANGLE DETECTION AND SEGMENTATION ALGORITHM OF PDF417 BAR CODE UNDER COMPLEX BACKGROUND

[1]GUOCHENG WANG,[2]GUOYAN ZHANG,[3]YANPENG MA,[4]YI LIU,[5]JIANHUA LI,[6]PING LI

[1,5,6]Microsystem and Integrated Design Center, uestc, CHINA

[2,3,4]School of Microelectronics and Solid-state Electronics, uestc, CHINA

E-mail: [1]wgch19890113@163.com, [2]1025442022@qq.com

**ABSTRACT**

PDF417 barcode identification is very sensitive to the skew angle while existing tilt angle detection algorithms are defective because of great calculation cost or high complexity or uncertain result. In this paper, a series of morphological transforms are applied to extract PDF417 out of complex background. Firstly, pre-process captured PDF417 images by noise removal and illumination equalization and then binarize it. Secondly, barcode's skew angle is detected through measuring eroded area by dot pair or linear structure element based on the PDF417 barcode's directional texture characteristics. Finally, reconstruction operation is utilized to obtain the full PDF417 barcode. The simulation shows that the algorithm can detect the PDF417 tilt angle exactly, and segment the barcode from complex noisy background.

**Keywords:** *PDF417 bar-code, texture analysis, morphology, skew angle detection, barcode orientation and segmentation*

## 1. INTRODUCTION

Barcode technology was launched in the United States in the 1940s, which is an automatic identification technology that combines data encoding, bar code printing, data acquisition and data processing. The 2-D barcode is widely used because of its characteristics such as high density, high capacity, high reliability, high error correction capability and strong security features.

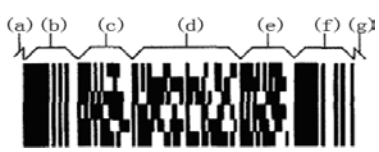


Fig.1 diagram of the PDF417 code

PDF417 barcode consists of left blank area (a), start pattern (b), left row indicator (c), codeword (d), right row indicator (e), stop pattern (f), and right blank area (g), as shown in Figure 1[1].

The 2-D barcode image processing mainly includes barcode orientation, skew angle detection, and barcode rotation, anti-perspective transformation and decoding operations. In practical applications, barcode image is usually exposed to complex environment and the barcode is susceptible to the limitations of barcode printing technology and image acquisition devices. In addition, the pollution derived from the circulation process brings great challenges to barcode identification. In this situation, skew angle detection and barcode orientation and segmentation become the key of the bar code recognition.

Currently, the main methods for barcode tilt angle detection and segmentation are: Hough transform, Fourier transform, wavelet multi-resolution analysis, scan segmentation method, as well as morphological method[2] and texture analysis[3].

Hough transform is the most common algorithm for angle detection, which flawed in great calculating cost[4].Fourier transform method transforms the image into frequency domain in which the direction with highest density of frequency domain space is the exact skew angle. [5]. Wavelet analysis can be used to detect the angle due to its intrinsic directional characteristics [6]. Projection method obtains the angle by calculating the cost function of the image Projection histogram in different angles [7]. The scan segmentation method requires high image quality, which is very sensitive to noise, and the same pattern of texture noise will result in failure[8].

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A PDF417 tilt angle detection and barcode orientation and segmentation method under complex background is proposed by morphological texture analysis on the basis of previous work.

## 2. MATHEMATICAL MORPHOLOGY (MM) AND TEXTURE ANALYSIS

A brief introduction about morphological basis and knowledge of texture analysis is essential before the algorithm is proposed.

### 2.1 Basis of mathematical morphology

MM is a theory of spatial structure analysis, whose purpose is to analyze the shape and structures of the concerned target. MM is widely used in the field of image processing and computer vision due to the powerful image analysis and image enhancement capabilities of morphological transformation. MM involves structural element set and image set. Morphological operations consist of dilation, erosion, opening, closing, and other derived transformations.

The result of the erosion operation to an image shows where the SE fits the objects in the image. In gray scale, eroding an image $f$ by SE $B$ is defined as:

$$[\varepsilon_B(f)](x)=\min_{b\in B} f(x+b) \quad (1)$$

The result of the dilation operation to an image shows where the SE hits the objects in the image. The dilation is defined as:

$$[\delta_B(f)](x)=\max_{b\in B} f(x+b) \quad (2)$$

The opening operation performs erosion followed by dilation; while the closing operation performs dilation followed by erosion. The idea behind opening is to dilate an eroded image in order to recover the eroded image as much as possible. In contrast, the closing is to recover the dilated image.

$$\gamma_B(f)=\delta_{\breve{B}}[\varepsilon_B(f)] \quad (3)$$

$$\phi_B(f)=\varepsilon_{\breve{B}}[\delta_B(f)] \quad (4)$$

Compared with MM opening operation, opening reconstruction can recover graphics which are not completely eroded by erosion. Opening reconstruction is defined as the morphology transformation that carries out geodesic dilation to the bounded image until stable.

Geodesic dilation involves two images: mark image $f$ and mask image $g$. When the scale value is $n$, geodesic dilation of mark image $f$ relative to mask image $g$ can be realized by continuously performing $n$ times geodesic dilations on $f$ relative to $g$.

$$\delta_g^{(n)}(f)=\delta_g^{(1)}[\delta_g^{(n-1)}(f)] \quad (5)$$

We get dilation reconstruction when geodesic dilation of $f$ relative to $g$ becomes stable.

$$R_g^{\delta}(f)=\delta_g^{(i)}(f) \quad (6)$$

In (6), $i$ represents iteration number.

Opening reconstruction is defined as to reconstruct the eroded image by dilation reconstruction.

$$\gamma_R^{(n)}(f)=R_f^{\delta}[\varepsilon^{(n)}(f)] \quad (7)$$

There exists another reconstruction operation called Condition dilation, which is defined as getting minimal value between the dilation result of mark image under $n$ scale and the mask image.

$$\tilde{\delta}_g^{(n)}(f)=\delta^{(n)}(f)\wedge g \quad (8)$$

### 2.2 Basis of texture analysis

Texture is commonly defined as the physical structure characteristic given to an object by the size, shape, arrangement, and proportions of its parts. The most common four kinds of texture analysis methods are[9]: statistical analysis method, the spectral analysis method, model analysis method and structural analysis method.

Statistical analysis method describes the image texture features by auto correlation function about statistical attributes from the image; spectral analysis method deals with image by transforming image from the spatial domain to the frequency domain; model analysis method assumes that the distribution of texture is based on some particular models and structural analysis method usually depends upon the geometric properties of the texture elements.

Due to the apparent structural characteristics of the PDF417 barcode, particularly its direction, the structural analysis method is a fine choice.

### 2.3 Structural features and global direction information of PDF417 barcode

PDF417 barcode consists of a series of bars and blanks which are parallel, particularly the start and stop characters have larger connectivity compared with the data region. However, the complex

Journal of Theoretical and Applied Information Technology
30th April 2013. Vol. 50 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

background of the barcode is generally impossible to contain a large number of parallel structures. Therefore, the parallelism between the bars and blanks makes it own a global directivity for PDF417 barcode, with which we can use a sequence of directional filters to filter the input texture, and detect the filtered results. Measure the volume of gray image (foreground pixels area for binary image) and plot area curve against different directions, and the peak value on the curve shows the main direction of the PDF417 barcode, which is the skew angle.[10]

## 3. PROPOSED ALGORITHM

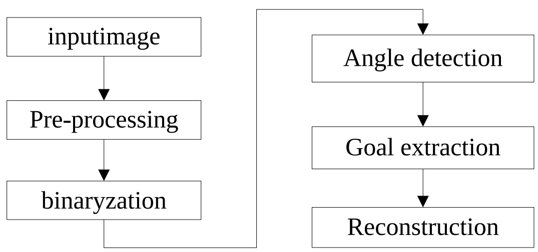


*Fig. 2 Flowchart Of The Proposed Algorithm*

PDF417 barcode can be seen as a valid image while considering unrelated background as noise for PDF417code under complex background. Thus, PDF417 segmentation from the background is to filter the noise. In MM, the selection of SE is usually determined based on a priori geometric knowledge of the image structure. Corresponding target can be obtained from image consistent with the relevant structure while non-related structures will be removed which is treated as noise. Due to the overall direction information of PDF417, linear structural elements that share the same directions with PDF417 are designed. And then a series of morphological operations are operated to remove noises whose directions are not associated with the PDF417 barcode and keep the concerned barcode.

*Fig.3 The Captured Image*

Figure 2 illustrates the flowchart of the proposed algorithm, which can be explained in the following 5 aspects, and Figure 3 illustrates the captured image of Chinese chars.

### 3.1 Pre-process of PDF417 barcode

The key of barcode recognition lies in the processing on acquired barcode image. Due to the complexity and changing of the image capture environment, as well as the impacts of the non-professional imaging sensor and interference of the transmission channel during the transmission process, the barcode image is usually accompanied by some degrees of noises and non-uniform illumination. Therefore, before the segmentation of PDF417 barcode, it's crucial for image denoising and image illumination equalization, and the result is shown in Figure 4.

*Fig.4 The Pre-Processed Image*

*Fig.5 The Binaryzation Image*

### 3.2 Image binaryzation

The Otsu algorithm is utilized to binarize the pre-processed image in order to extract the PDF417 barcode out of the background. The method divides image into background and target to ensure their inter-class variance greatest based on the image grayscale characteristics. The bigger the variance is, the bigger the difference between the two parts of the image is, meaning the least possibility to divide the background into target or the target into background wrongly. The result is shown in Figure 5.

**Journal of Theoretical and Applied Information Technology**
30th April 2013. Vol. 50 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

### 3.3 Access to barcode directional information by eroding with a pair of points SEs

In practical applications, the common directional SEs have two types. The first one considers a pair of points at fixed distance with a given direction, which is often used to probe the main directional information of the image.[10]

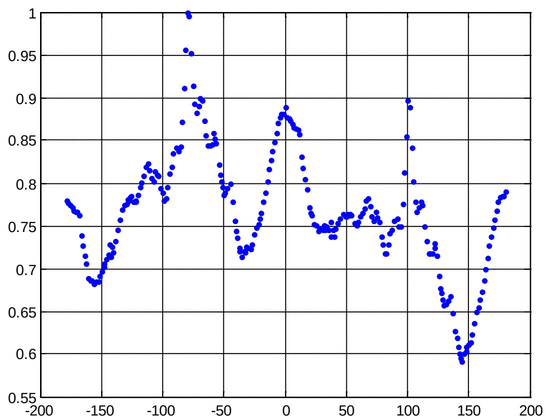


*Figure 6 Measure Of The Erosion Of PDF417 Using A Pair Of Points At Fixed Distance As SE*

In Figure 6, the abscissa represents the direction angles, and the ordinate represents the Measure of the erosion i.e. the normalized area of the binary image after image being eroded.

When PDF417 barcode is eroded by a pair of points whose direction is coincident with the PDF417 global direction, the image erosion is less than erosions in other directions. The corresponding peak value in curve clearly shows the texture linear direction i.e. skew angle of the barcode, the angle of this image is -80 degree as shown in Figure 6.

### 3.4 Access to barcode main goal by corrosion with linear SEs

Although global direction information of barcode can be accurately got through a pair of points, the complex background noises are filtered out incompletely and the barcode cannot be extracted out, as shown in Figure 7. In this case, the second type of SEs line is a good choice which is suitable for texture containing connectivity direction.

Applying directional line to erode PDF417 code, when the line direction is coincident with PDF417's global direction, the image erosion is less than erosion in other directions. Then, the corresponding peak value in curve clearly reveals the texture linear direction i.e. skew angle of barcode that is equal to -80 degree, as shown in Figure 8.

*Fig.7 Image Eroded By Dot Pair SE*

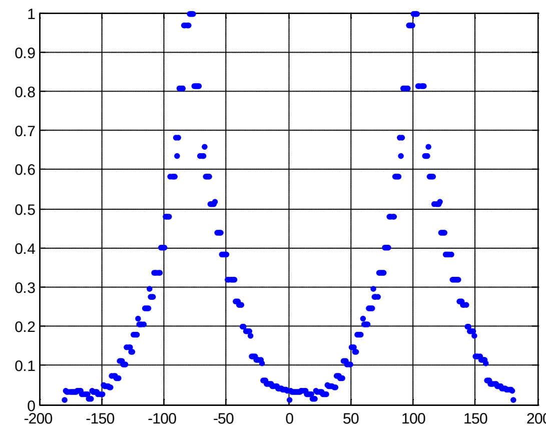


*Figure 8 Measure Of The Erosion Of PDF417 Using Lines At Fixed Distance As SE*

In Figure 8, the abscissa represents the direction angles, and the ordinate represents the Measure of the erosion i.e. the normalized area of the binary image after image being eroded.

Image eroded by lines whose direction is consistent with the bar code direction is shown in Figure 9, and the barcode is basically extracted out.

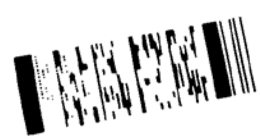

*Fig.9 Image Eroded By Linear SE*

From the above analysis, we can choose a pair of points or lines as SEs to erode image and obtain area measure to determine the image direction. But the PDF417 barcode cannot be extracted out using dot pair SE, while it needs more computing cost if line is chosen as SE.

To make a compromise, the paper firstly erodes the image with dot pairs as SEs with different directions to determine the direction information of barcode. Then linear SE whose direction matches the direction of barcode is adopted to erode the image to filter out most of the background that mismatches the barcode

Journal of Theoretical and Applied Information Technology
30th April 2013. Vol. 50 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

direction. Thus we can get the main objective of the barcode. Unfortunately, the barcode obtained already loses a lot of information, and will result in great errors if used for further image rotation and decoding processing.

### 3.5 Reconstruct PDF417 barcode to restore the missing information

In order to restore all information carried by the barcode, reconstruction operation is considered to repair the barcode.

Compared with MM opening operation, opening reconstruction can recover graphics which are not completely damaged by erosion, as shown in Figure 10.

*Fig.10 Results Of Opening Or Opening By Reconstruction Respectively*

However, another problem arises. After the previous processing, parts of the internal data area structure which have little connected region have been completely removed. Therefore, the opening reconstruction operation cannot completely repair the barcode reliably.

Another reconstruction method is also presented based on closing operation because of its hole filling capability. The method also involves two images: the mark image and the mask image.

*Fig.11 Closing To Fill Holes*

The image after the previous opening operation is taken as the mark image. Closing operation is used to fill the barcode's internal holes to restore the internal data information which is completely damaged, as shown in Figure 11.

Obviously, closing operation will inevitably leads to spread of the barcode, i.e. some parts originally belong to the background area will be converted into foreground structure. By limiting the image under the mask image, we can solve this problem. Since the binarization image which contains the background noise does not lose barcode information, we take the binarization image as mask image. Final extracted PDF417 bar code image is shown in Figure 12. We can see that the barcode is completely extracted out, without losing data information.

*Fig.12 Result After Reconstruction*

## 4 Another example

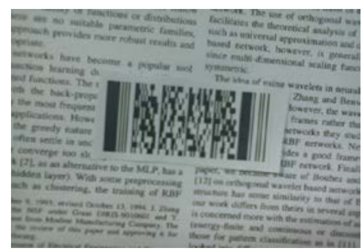

*Fig.13 The Captured Image*

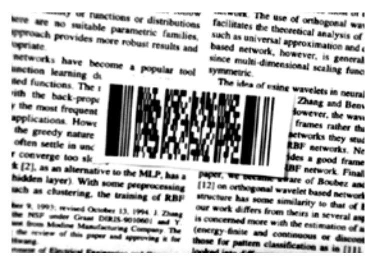

*Fig.14 The Pre-Processed Image*

In order to validate the effectiveness of the algorithm, the method is presented to another extra captured PDF417 pictures whose tilt angle is 117 ° with English chars background, and satisfactory result is obtained.

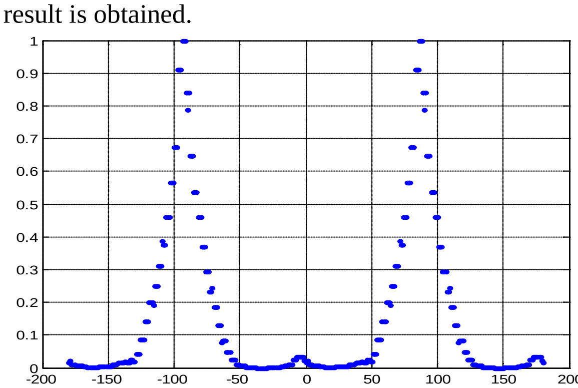


*Fig.15 Measure Of The Erosion Of PDF417 Using Lines At Fixed Distance As SE*

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 13 shows the captured primitive image; figure 14 shows result after illumination equalization processing and the corrosion area measurement is shown as figure 15. Due to the corrosion measurement with pairs SE, without symmetrical character, is less distinct, so the result of corrosion measurement with lines SEs is displayed. And figure 16 shows the final segmentation results.

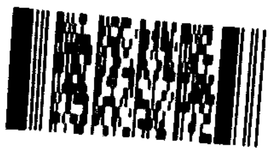

*Fig.16 Final Result After Reconstruction*

## 5 CONCLUSION

This paper presents a method to detect PDF417 barcode tilt angle and extract out the barcode under complex background. Since captured images will inevitably be subject to the impacts of noise and uneven illumination, mathematical morphology is used to process the image through noise removal and illumination equalization, and then a simplified binarization method by dividing the image into several blocks is adopted to binarize the pre-processed image. After that, we use a pair of points and linear as SEs with different directions respectively to erode the binarization image and the peak value of the erosion measure indicates the global direction information of PDF417 barcode, i.e. the skew angle of the barcode. Finally, morphological reconstruction algorithm is applied to segment the full PDF417 barcode from the complex background.

In the future subsequent research, we will focus on generalizing the segmentation method to other two-dimensional barcodes such as QR code and Data-matrix code and designing ASIC to implement the algorithm.

## REFRENCES:

[1] State Standard of the People's Republic of China GB/T17172—1997, China Standard Press, 1998.8.

[2] Chunhui Zhang, Jian Wang, Shi Han, Mo Yi. “Automatic real-time barcode localization in complex scenes”, [C]//International Conferences on Image Processing, pp. 497-500, (2006).

[3] Jain A K, Chen Y. “Bar code localization using texture analysis”, [C] // IEEE Proceedings of the 2nd International Conference on Document Analysis and Recognition, pp. 41-44, (1993).

[4] Thuy Tuong Nguyen, Xuan Dai Pham, Jae Wook Jeon. “An improvement of the Standard Hough Transform to detect line segments”, IEEE International Conference on Digital Object Identifier, pp: 1 – 6, (2008).

[5] Ohbuchi, E. Hanaizumi. H. , Hock, L.A. , “Barcode Readers using the Camera Device in Mobile Phones”[C], Proceedings of the 2004 International Conference on Cyber worlds, pp. 260-265, (2004).

[6] Amara Graps. “An Introduction to Wavelets” [J]. IEEE Computational Science and Engineering, 2(2), pp. 50-61, (1995).

[7] Smith R. “A Simple and Efficient Skew Detection Algorithm Via text row accumulation”, [C] // Proceedings of 3rd International Conference on Document Analysis and Recognition. Montreal; 1145-1148, (1995).

[8] Wei Wei-bo Rui Xia o-t ing. “Study on Edge Detection Met hod” [J]. Computer engineering and application, 30, pp. 88-91. (2006)

[9] C. H. Chen, L. F. Pau, P. S. P. Wang. “Texture Analysis”. The Handbook of Pattern Recognition and Computer Vision (2nd Edition), pp. 207-248, (1998).

[10] Soille. “Morphological Texture Analysis: An Introduction”, Lecture Notes in Physics. 6000, pp. 215-237. (2002b).